INTERIM SURVEY REPORT:

RECOMMENDATIONS FOR ERGONOMICS INTERVENTIONS

FOR SHIP REPAIR PROCESSES

at

CONTINENTAL MARITIME OF SAN DIEGO, INC. SHIPYARD, San Diego, California

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PLANT SURVEYED:	Continental Maritime of San Diego, Inc. shipyard, 1995 Bay Front Street, San Diego, California 92113-2122
SIC CODE:	3731
SURVEY DATE:	June 7-8, 2000
SURVEY CONDUCTED BY:	Stephen D. Hudock, NIOSH Steven J. Wurzelbacher, NIOSH Karl V. Siegfried, MEMIC
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EMPLOYEE REPRESENTATIVES CONTACTED:	Not Applicable

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Mention of company names and/or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC).

ABSTRACT

A pre-intervention quantitative risk factor analysis was performed at various shops and locations within Continental Maritime of San Diego, Inc. shipyard in San Diego, California, as a method to identify and quantify ergonomic risk factors that workers may be exposed to in the course of their normal work duties. This survey was conducted as part of a larger project, funded through the Maritech Advanced Shipbuilding Enterprise and the U.S. Navy, to develop projects to enhance the commercial viability of domestic shipyards. The application of exposure assessment techniques provided a quantitative analysis of the risk factors associated with the individual tasks. Based on ergonomic task analyses, four ergonomic interventions are suggested for at Continental Maritime: 1) upright scaling, chipping, and needle gun tools for the deck scraping process or 2) wheeled, adjustable work stools and knee supports for the deck scraping process and for other workers performing prolonged kneeling or squatting tasks 3) portable workbenches for the duct installation process 4) worker awareness training for welders/ grinders working overhead or in confined spaces (such as those in the in onboard deck fitting and pipe welding processes).Of these interventions, it is expected that the upright scaling, chipping, and needle gun tools and portable workbenches will have the most effective impact on reducing musculoskeletal injuries, and therefore they are the most strongly recommended changes. Detailed descriptions of each intervention are provided including cost benefit analysis where appropriate.

I. INTRODUCTION

IA. BACKGROUND FOR CONTROL TECHNOLOGY STUDIES

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposures to potential chemical and physical hazards, as well as the engineering aspects of health hazard prevention and control.

Since 1976, NIOSH has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of the completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

IB. BACKGROUND FOR THIS STUDY

The background for this study may be found in the previous report no. 229-14a, "Preliminary Survey Report: Pre-Intervention Quantitative Risk Factor Analysis for Ship Repair Processes at Continental Maritime of San Diego, Inc. shipyard in San Diego, California " by Hudock and Wurzelbacher, 2001.

IC. BACKGROUND FOR THIS SURVEY

The Continental Maritime facility was selected for a number of reasons. It was decided that the project should look at a variety of yards based on product, processes and location. Continental Maritime is one of the principal SRA (Selected Restricted Availability), or scheduled maintenance, providers for the U.S. Navy. Continental Maritime is a certified Master Ship

Repair Contractor (MSRC) with the U.S. Navy. Continental Maritime repairs and overhauls military vessels including aircraft carriers, cruisers, destroyers and frigates, numerous types of amphibious and auxiliary ships, as well as commercial vessels. Continental Maritime is considered to be a small- to medium-size yard.

II. PLANT AND PROCESS DESCRIPTION

IIA. INTRODUCTION

Plant Description: The Continental Maritime shipyard is located on San Diego Bay in southern San Diego, California. The shipyard consists of 14 acres of land and 18 acres of water. Production, administration, and warehouse facilities exceed 300,000 square feet under roof in addition to outside steel fabrication and material storage areas. Continental Maritime operates six piers up to 700 feet in length with a berthing draft of about 35 feet.

Corporate Ties: Continental Maritime of San Diego, Inc. is a Newport News Shipbuilding Company, providing a West Coast facility for them, in addition to the Newport News Shipbuilding yard in Virginia.

Products: Continental Maritime has completed hundreds of ship repair contracts for the U.S. Navy including: Regular Overhaul (ROH), New Threat Upgrade (NTU), Selected Restricted Availability (SRA) and Drydock Selected Restricted Availability (DSRA). Repairs and alterations have been completed on combatant systems, hull, mechanical, and electrical systems and habitability concerns. Most of these contracts allow only a very limited timeframe in which the work must be completed and the vessel returned to active duty.

Age of Plant: Approximate age of shipyard facilities is 25 years.

Number of Employees, etc: As of the date of the survey, based on the number of employee hours, Continental Maritime employed the equivalent of about 215 full-time production workers. However, due to the sporadic nature of repair work, the actual number of employees, including part-time and full-time, is closer to 400.

IIB. SELECTED PROCESS DESCRIPTIONS

Four specific processes were identified for further analysis. These processes were: onboard deck scraping, onboard duct installation, onboard deck fitting, and onboard pipe welding. Each of these processes are examined in greater detail below.

IIB1. Onboard Deck Scraping Process

When a vessel is in a yard for scheduled maintenance, often the exterior deck's surface must be replaced with a new coating of high-friction anti-slip material. First the old coating must be removed. This is accomplished by using large machines, similar in size and function to commercial floor sanders. However, there are usually numerous fixtures and encumbrances on the deck surface, such as ladders and machinery mounting brackets. Around these fixtures and in the area between the deck and the bulkheads, the old coating must be removed be using a variety of pneumatic tools including deck scalers, needle guns and scrapers. Common work postures for this task can be seen in Figures 1- 5. Since all this work is done at deck level, workers must squat, sit, kneel, crawl or lie down in order to reach all the areas that must be stripped of the old coating. Stresses to the lower extremities, neck and back can be quite high depending on the worker posture, whether the posture is constrained, and the length of time the worker must assume that posture. Exposure to the vibration created from using pneumatic vibrating hand tools may lead to hand-arm vibration syndrome or carpal tunnel syndrome.

Figure 1. Deck Worker #1 Oiling Tool

Figure 2. Deck Worker #1 Changing Tools

Figure 3. Deck Worker #1 Using a Deck Crawler

Figure 4. Deck Worker #1 Using Pneumatic Scraper

Figure 5. Deck Worker #2 Using Needle Gun

IIB2. Duct Installation Process

When a vessel is in the yard for scheduled maintenance, often work is done to the ventilation or exhaust systems onboard. Ductwork can be removed, replaced, or installed initially depending on the proposed work. Working with ductwork is most easily performed on the deck rather than overhead. Common work postures are shown in Figures 6-8. Duct installation or removal usually requires overhead work to place or remove the duct from its position. Static postures and overhead work may cause strain to the workers' shoulders and neck. Once a piece of duct is on the deck, the worker usually bends over top of it to perform some part of the work process. The back flexion may result in some strain to the worker. The use of powered hand tools, such as grinders or reciprocating saws, exposes the worker to some amount of hand-arm, or segmental, vibration.

Figure 6. Duct Worker Using Angle Grinder

Figure 7. Duct Worker Cutting Flange

Figure 8. Duct Workers Lowering Duct from Overhead

IIB3. Onboard Deck Fitting Process

Often during scheduled maintenance activities, portions of the deck of a ship must be removed and refitted to allow access to the areas below for equipment that is being removed or added in the space below. This work requires workers to cut out the deck plate and then weld it back in place when the access hole is no longer required. This work may require workers to work overhead from below the plate to weld or grind off the weld splatter. Examples of common work postures are shown in Figures 9 and 10. The overhead work may place strain on the neck and shoulders of the worker. Welding also requires static and prolonged postures in occasionally awkward postures to complete the necessary weld. Exposure to welding fumes is another consideration.

Figure 9. Welder Stick Welding Overhead

Figure 10. Worker Using Needle Gun Overhead

IIB4. Onboard Pipe Welding Process

During scheduled maintenance activities, piping for the movement of liquids and steam, may have to be repaired or replaced. Often the piping is located against a bulkhead or the hull of the ship limiting access to the piping. Welders will often use stick welding equipment to complete the weld. Typical work postures are shown in Figures 11 and 12. Stick welding requires static and often awkward postures of the arms of the worker resulting in strain. The neck or back of the worker may be flexed to accommodate viewing the work task. The worker may have to kneel, squat or lay down in order to complete the task. Therefore, the lower extremities may be strained as well as the upper extremities. The possibility of working in confined spaces resulting in awkward postures is relatively high.

Figure 11. Worker Bending to Weld Pipe Onboard Vessel

Figure 12. Worker Using Hammer to Deslag Pipe Weld

III. ERGONOMIC INTERVENTION COST JUSTIFICATION

The following section has been adapted from the article by Alexander, 1998.

The effectiveness of any ergonomic intervention does not necessarily correlate with the cost of implementing that intervention. The possibility exists for a very effective intervention to be found at a low implementation cost, as well as, the possibility of the opposite. The preferred intervention strategy from a business sense is to implement those interventions with the lowest costs and the highest effectiveness. This point can be illustrated by the value/cost matrix as illustrated in Figure 13.

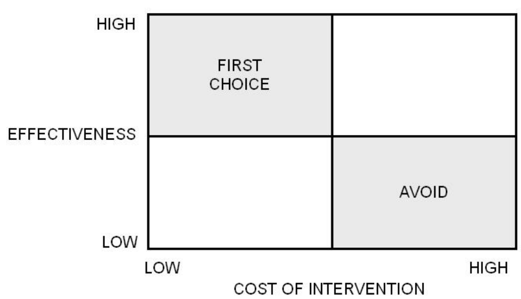

Figure 13: Value Cost Matrix

There are a number of benefits that can be credited to the application of ergonomic interventions in general. These benefits are listed below.

- Avoidance of current expenses and ongoing losses, including:
  - Workers compensation costs
  - Overtime for replacement workers
  - Lost productivity, quality or yields from less skilled workers
  - Increased training and supervisory time

- Enhanced existing performance
  - Increased productivity including fewer bottlenecks in production, higher output, fewer missed delivery dates, less overtime, labor reductions, and better line balancing
  - Improved quality including fewer critical operations, more tasks with every operator's control and capacity, and fewer assembly errors
  - Increased operating uptime including faster setups, fewer operating malfunctions, and less operator lag time.
  - Faster maintenance including increased access, faster part replacement, fewer tools needed, more appropriate tools, more power and faster tool speeds.

- Enhanced quality of work life
  - Less turnover
  - Less employee dissatisfaction

- Fewer traumatic injuries

- Fewer human errors resulting in lost product or operating incidents

- Reduced design and acquisition costs

In addition to the direct medical costs associated with worker injuries, one must also consider the indirect or hidden costs associated with the primary worker being away from their job. These indirect costs are listed below.

- Costs of replacement workers
  - Hiring costs for permanent replacements plus training and other costs
  - Additional costs for temporary workers who may also have lower work skills

- Lower productivity
  - Fewer units per hour
  - Lower yields
  - Damage to material or equipment that would not occur with an experienced worker

- Lower quality
  - – Number of rejects
  - – Amount of rework
  - – Timeliness of product delivery

- Increased supervision
  - – Cost to manage/train a less skilled worker

- Training to develop and maintain job skills
  - – Amount of lost work time
  - – Time of trainer.

Many of these indirect costs are difficult to estimate and can vary widely depending on the severity of the injury involved. The ratio of indirect costs to direct costs has also been found by a number of studies to vary between 5:1 to 1:5, depending on industry (Heinrich, 1931, 1959; Levitt et al, 1981; Andreoni, 1986; Leopold and Leonard, 1987; Klen, 1989; Hinze and Applegate, 1991; Oxenburgh, 1991, 1993). As a conservative estimate, the state of Washington recently decided upon indirect costs of 75 percent of direct workers' compensation incurred costs (WAC 296-62-051, 2000).

Another aspect of ergonomic interventions that must be considered is the cost benefit analysis. One has to determine the associated start-up costs, recurring costs, and salvage costs of the intervention as well as the time value of money (present worth versus future worth) and the company's Minimum Attractive Rate of Return, the interest rate the company is willing to accept for any project of financial undertaking. In addition, from a public health perspective, the welfare of the worker must also be considered in the decision to implement an intervention.

IV. CONTROL TECHNOLOGY

The following section presents various ergonomic interventions that are recommended for implementation at Continental Maritime. These recommendations are based on the risk factor analysis that was performed at Continental in June of 2000 and detailed in a previous NIOSH report (No. 229-16a).

IVA. Possible Interventions for the Onboard Deck Scraping Process

Although large scaling machines are difficult to use around various encumbrances on the deck surface, there are commercially available long-handled pneumatic tools including deck scalers, needle guns and scrapers. These may reduce the need for the worker to squat, sit, kneel, crawl or lie down in order to reach all the areas that must be stripped of the old coating and may reduce the exposure to vibration. Suggested approximate long-handled tool characteristics are shown in Table 1. Setup and training time is negligible. Total cost for a crew size supply of long handled pneumatic tools is estimated to be $4,700. Smaller electric upright deck scalers may also be used in areas typically too small for bulkier scalers. These units are in the same price range as the hand held tools for a crew size supply, though the hand tools have more versatility.

Table 1: Approximate Long- Handled Scaling Tool Characteristics	
Long- Reach Chisel/ Needle Scaler (depicted in Figures 14 a, b)	
Weight	6.6 to 13.5 lbs
Length	range from 29" to 67"
Blows per minute	2200
Air Consumption	2.1 lps (4.5 cfm @ 90 psi); can be powered by a 1.5 - 2 hp compressor
Other Features	• single tool converts between needle scaler and chisel in seconds • wide range of chisel and scraper blade widths available
Price	$235 * 20 (crew size) = $4,700
Electric Upright Scalers/ Deck Crawler (depicted in Figure 15)	
Weight	32 lbs
Dimensions	11" * 37.4" * 35.4"
Capacity	up to 6 m^2 per hour
Other Features	• can be used in smaller areas, spot scaling, along edges
Price	$225 * 20 (crew size) = $4,500

Figures 14 a, b. Examples of Long-Handled Needle De-scalers and Chisels
(photos courtesy of Trelawny Surface Preparation Technology)

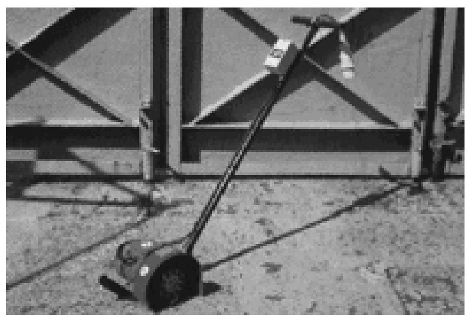

Figure 15. Example of Electric Upright De-scalers Useful for Constrained Areas
(photo courtesy of Rustibus)

Another option for the deck scrapers is the use of commercially available seats, such as that depicted in Figures 16, designed specifically for kneeling and squatting. These seats may at least improve the postures associated with the use of hand-held scraping tools by enabling the worker to sit to lessen the stress on the knees while still enabling the worker to perform the assigned task at or near floor level without additional strain on the lower back. Supports (See Figures17a and 17b) are also commercially available that attach to the back of the calf to prevent over flexion of the knees during squatting postures.

Figure 16. Example of Stool Designed for Prolonged Kneeling Tasks
(photo courtesy of Racatac Products Inc.)

Figures 17a, b. Example of knee support device useful for tasks requiring extended squatting

Suggested approximate work stool characteristics are shown in Table 2. Setup and training time is negligible. Total cost for a crew size supply of stools and knee supports is estimated to be $4,180.

Table 2 Approximate Work Stool/ Knee Support Characteristics	
Wheeled Work Stool	
Weight	8 lbs
Dimensions	19.5 " x 20"
Capacity	300 pounds
Adjustable Seat	vertical travel: 11.5 " to 15.5 " in height horizontal travel: 3 "; tilts
Other Features	7" x 15" tool tray
Price	$169 per stool * 20 (crew size) = $3380
Knee Supports (See Figures 30a and 30b)	
Price	$40 pair *20 (crew size) = $800
Total Price	$4,180

In identifying benefits of the intervention, one can use the medical and indemnity cost estimates as shown in Table 3 to calculate direct costs.

Table 3: Estimated[1] Shipyard Direct Injury Costs for Musculoskeletal[2] Injuries (medical + indemnity) by Part of Body [1] Based on analysis of available participating shipyard compensation data from 1996 - 1998 [2] Does not include contusions or fractures	
Ankle(s)	$2,390
Arm(s), unspecified	$7,725
Back	$6,996
Elbow(s)	$4,691
Finger(s)	$735
Hand(s)	$6,857
Knee(s)	$7,472
Leg(s), unspecified	$849
Neck	$5,961
Shoulder(s)	$4,960
Wrist(s)	$3,925
Mean Musculoskeletal Injury Cost = $5,523	

Since the provided Continental injury logs do not include a narrative describing how the injury occurred, it is difficult to determine exactly how many knee injuries that are recorded were due to deck scraping tasks. However, from 1993 to 1998 Continental experienced 16 knee, back, and neck injuries and to shipfitters, painters, and tile mechanics. The total estimated medical and indemnity cost of these injuries was $109,866, based upon the above shipyard industry average costs by part of body injured. If the sixteen injuries can be said to be due to poor postures and contact stress, the average annual estimate direct cost (over the last five years) for musculoskeletal injuries that may be preventable by measures to relieve these postures and stresses is $18,311. If indirect costs are conservatively assumed to be 75% of the direct costs, the total cost of these injuries per year is $32,044. It is this amount that can be considered an "avoided cost" and, therefore, a benefit due to the implementation of the intervention. Assuming the long handled pneumatic tools intervention fully eliminates such injuries, a simple benefit to cost ratio would be $32,04463,089/$4,700 or 6.8. Since the benefit to cost ratio is greater than one, it is advantageous and cost-effective to implement the proposed intervention. However, it is likely that not all of the injuries were associated with deck scraping and that the intervention will not eliminate all those injuries due to the awkward postures required for the tasks. Thus, one may estimate that only one-tenth of the estimated annual injury cost is saved each year. It is also possible that the long-handled scaling tools last 2 years. Assuming that the shipyard has a minimum attractive rate of return of 20 percent for any project cash outlay, one can still calculate a benefit to cost ratio by utilizing the following equation to determine the present worth of an annual savings:

Equation 1: $$PW = AS \times \frac{\left[(1+i)^n - 1\right]}{i \times (1+i)^n}$$

where *PW* = present worth
AS = annual savings
i = interest rate (ex., 0.20 for 20 percent)
and *n* = number of years.

Using an annual savings of just $3,204 (one-tenth of the estimated annual injury cost) at an interest rate of 20 percent over a half year period, the present worth of the proposed savings would be $4,896. Assuming initial costs of the scaling tools are $4,700 and negligible annual costs, the benefit to cost ratio of implementing this intervention is $4,896/ $4,700 or 1.04, greater than one, and therefore still economically advantageous.

IVB. Possible Intervention for the Duct Installation Process

A commercially available portable workbench may be used to position the piece of duct at a height sufficient to reduce back flexion and the need to kneel while the worker performs a variety of operations on the duct. Many of these benches come equipped with vises or strap-downs which can be used to secure the duct during work and eliminate the need for a second worker. Table 4 and Figure 18 provides estimated specifications and costs for a portable work bench for the duct installation process.

Table 4: Approximate Portable Workbench Characteristics

Weight Capacity	300 lbs
Dimensions	20" * 24"
Weight	20 lbs
Other features	29 Inch Vise Jaw
Total Price	$87 * 20 (crew size) = $1,740

Figure 18. Example of Portable Workbench
(photo courtesy of Grainger and DeWalt)

In identifying benefits of the portable work bench intervention, one can again use the medical and indemnity cost estimates as shown in Table 2 to calculate direct costs. Since the provided Continental injury logs do not include a narrative describing how the injury occurred, it is difficult to determine exactly how many back injuries that are recorded were due to tasks similar to duct installation. However, from 1993 to 1998 Continental experienced 17 back and knee injuries to sheetmetal workers and pipefitters. The total estimated medical and indemnity cost of these injuries was $120,360, based upon the shipyard industry average costs by part of body injured in Table 2. The average annual estimate direct cost (over the last six years) for these injuries is $20,060. If indirect costs are conservatively assumed to be 75% of the direct costs, the total cost of these back injuries per year is $35,105. Assuming the portable workbenches fully eliminate only one- twentieth of the yearly costs, the “avoided cost” or a benefit due to the intervention would be would be $1,755 per year. If the workbenches are assumed to last two years and assuming that the shipyard has a minimum attractive rate of return of 20 percent for any project cash outlay, one can calculate a benefit to cost ratio by utilizing the following equation to determine the present worth of an annual savings:

Equation 1: $$PW = AS \times \frac{\left[(1+i)^n - 1\right]}{i \times (1+i)^n}$$

where PW = present worth
AS = annual savings
i = interest rate (ex., 0.20 for 20 percent)
and n = number of years.

Using an annual savings of just $1,755 (one-twentieth of the estimated annual injury cost of back injuries) at an interest rate of 20 percent over a two year period, the present worth of the proposed savings would be $2,682. Assuming initial costs of the workbenches of $1,740 and negligible annual costs, the benefit to cost ratio of implementing this intervention is $2,682/ $1,740 or 1.54, greater than one, and therefore economically advantageous.

IVC. Possible Interventions for the Onboard Deck Fitting Process and Onboard Pipe Welding Processes

Although welding/ grinding in confined spaces and overhead are difficult processes to address with engineering controls, workers may benefit from ergonomic training. A free training program, which offers tips on reducing the effects of static and constrained postures by rest breaks and stretching exercises specific to the shipyard industry, has been developed by NIOSH. Management is also encouraged to provide administrative controls in terms of worker rotation and scheduling to reduce the time individual workers are assigned to such tasks. The use of teams (which alternate between set-up work and welding) is one such method observed in a number of shipyards.

V. CONCLUSIONS AND RECOMMENDATIONS

Four distinct construction processes were examined at Continental Maritime to quantify the musculoskeletal risk factors associated with these processes. The processes included: onboard deck scraping, onboard duct installation, onboard deck fitting, and onboard pipe welding. Based on ergonomic task analyses, four ergonomic interventions are suggested for at Continental Maritime: 1) upright scaling, chipping, and needle gun tools for the deck scraping process or 2) wheeled, adjustable work stools and knee supports for the deck scraping process, and other processes involving prolonged kneeling or squatting tasks 3) portable workbenches for the duct installation process 4) worker awareness training for welders/ grinders working overhead or in confined spaces (such as those in the in onboard deck fitting and pipe welding processes).Of these interventions, it is expected that the upright scaling, chipping, and needle gun tools and portable workbenches will have the most effective impact on reducing musculoskeletal injuries, and therefore they are the most strongly recommended changes.

The implementation of engineered ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries. However, each of the interventions proposed in this document are to be considered preliminary concepts. Full engineering analyses by the participating shipyard are expected prior to the implementation of any particular suggested intervention concept to determine feasibility, both financially and engineering, as well as to identify potential safety considerations.

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